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Performance Evaluation of STF codes with Pre-DFT processing of MIMO-OFDM Systems

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Abstract: The main aim of this paper is to propose an approach to reduce the system complexity of the conventional MIMO-OFDM system by reducing the number of DFT processing blocks corresponding to the receiver antennas at the receiver side. This is going to be achieved by processing the received data bits even before it is sent for processing by the space-time-frequency (STF) decoder. This results in the size reduction of the MIMO-OFDM system. Here we use a weighting coefficients calculation algorithm unlike others which are more relevant to STF coding used, this algorithm can be used for most of the STF schemes in the real time applications which is the main advantage for MIMO systems. In the proposed technique, there is no restriction on the number of the DFT processing blocks which can be used at the receiver side. They can range from one to total receiver antennas. This leads to the complexity reduction and cost minimization.

***Index Terms* - MIMO-OFDM, Weighing Coefficients, STFC**

I. Introduction

The Orthogonal Frequency Division Multiplexing (OFDM) is one of the modern-day techniques used for very high-speed data transfer wireless communication systems. To get high data rate and accuracy to the data transfer, the traditional OFDM can be used along with combined deployment of Multiple-Input Multiple-Output (MIMO) technology [1]. But in traditional OFDM, many subcarriers were employed simultaneously for the transfer of information and to obtain optimal performance. The general subcarrier-based processing requires multiple discrete Fourier transform/ inverse Discrete Fourier transform (DFT/IDFT) blocks, one DFT/IDFT block is required for one antenna at the receiver side.[4][9]. MIMO is nothing but a wireless link between transmission and reception side. But unlike conventional wireless systems, MIMO uses not one but more than one number of transmitter and receiver antennas. The total number of antennas deployed mainly depends on the purpose of usage and maximum throughput required power distribution of antennas etc. MIMO can be advantageous in real time applications where multipath signal fading is prominent. MIMO uses advance algorithms which employ DSP processors to enhance bandwidth and efficiency of a communication link. In general, the channel state information (CSI) is necessary to be known to the transmitter for the processing of signal at the receiver. But in mobile environment, the channel varies very swiftly and it is a difficult task to maintain the precise channel state information at the transmitter. Even though we try to maintain CSI explicitly, additional bits are required with may increase the system overhead. Because of this, system overhead increases considerably. Space-Time-Frequency codes were proposed to solve this problem in OFDM. In the case of frequency selective fading channels, the diversity in frequency can be exploited without the complete CSI at the transmitter to obtain better performance.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

In OFDM, the subcarriers are orthogonal that means their frequencies are deployed to be orthogonal to each other which can reduce the intermixing of the transmitted symbols known as ISI (Inter symbol interference). By this, we can make the designs of transmitter and receiver easier, unlike traditional FDM, we do not need a different guard filter for each subchannel. The main use of orthogonality is that it has symbol rate almost equal to Nyquist rate which helps to achieve good spectral efficiency. Because OFDM's spectrum is almost 'white,' it has low electromagnetic interference qualities as compared to other co-channel users. OFDM should have very precise sync between transmitter and receiver blocks, if the frequency is off, the orthogonal property of the subcarriers might be lost resulting in inter-carrier interference (ICI). Doppler shift like extreme cases can result into non synchronization. While Doppler shift can be easily corrected by the receiver in some cases. But it is difficult for the receiver to correct the orthogonality when doppler shit is mixed with reflections because of the multipath fading effects. This impact often intensifies as speed increases, and it is one of the main reasons why OFDM isn't used in high-speed vehicles. Several ICI suppression strategies are proposed, although they may increase receiver complexity.

III. MIMO-OFDM SYSTEM

The OFDM carrier is the combination of many subcarriers, with information on each sub-carrier being modulated individually using different modulation schemes, generally QAM or PSK. This combined signal is used to modulate the original RF carrier. s[n] is a binary digit serial stream. The signal is first divided into individual signal streams and each individual stream of data is mapped to a complex constellation using modulation techniques such as QAM, PSK. Because the constellations may vary, certain streams might have a higher bit rate than others Each set of symbols is subjected to an IFFT, resulting in a set of complex time-domain values. After that, the samples are quadrature-mixed to passband in the traditional fashion. The role of Digital-to-analogue converters (DACs) analogue data changing; Cosine and sine waves, are modulated by using these analogue signals respectively. The transmission signal s[t] is created by adding these signals together. The receiver of the MIMO-OFDM idealised receiver system is shown below. The signal r(t) is picked up by the receiver and quadrature-mixed to original signal using cosine and sine waves at the carrier frequency

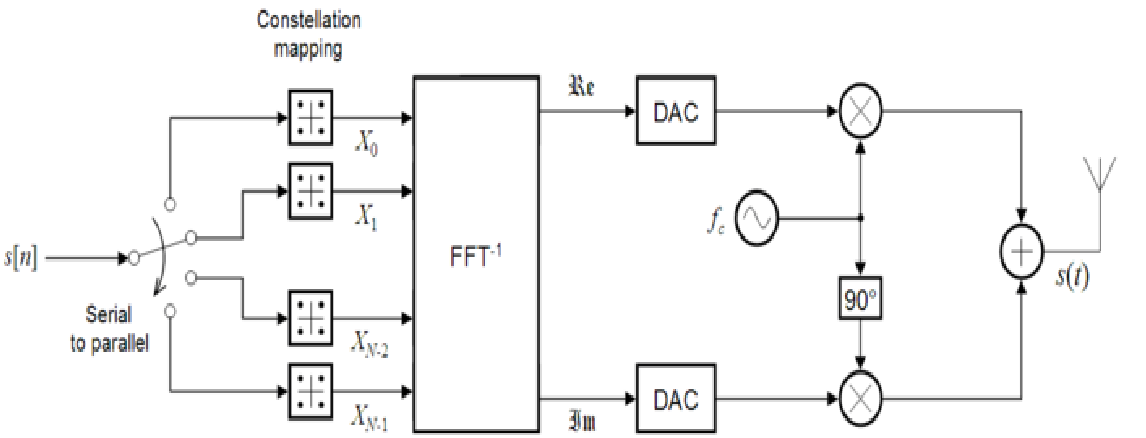

fig 1. Block Diagram of MIMO-OFDM transmitter

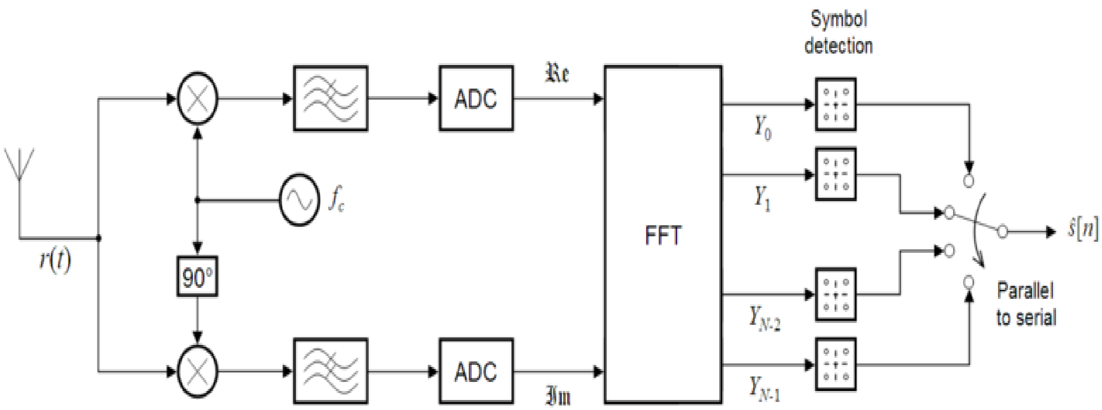

fig 2. Block Diagram of MIMO-OFDM receiver

Low-pass filters are employed to reject signals centred on 2fc as a result of this. Analogue-to-digital converters (ADCs) sample and digitise the baseband signals, and a forward FFT is employed to convert back to the frequency domain. N parallel streams are returned, each of which is transformed to a binary stream using the appropriate symbol detector. These data streams are then again mixed into a serial stream, s[n], which is a close approximation of the original binary stream at the transmitter.

Space -Time-Frequency Coding

IV. SPACE TIME FREQUENCY CODING

We consider a Space time frequency encoded MIMO-OFDM system with "Mt" transmission antennas, "Mr" reception antennas and "N" number of sub-carriers. Imagine the channel to be frequency selective fading channel. There are L number of delay paths all with same delay profile. Let us assume that MIMO channel is static over each individual block period, but might vary at different OFDM blocks . At the k-th OFDM block, the impulse response of the fading channel from transmit antenna i to receive antenna j at time τ can be modelled as $H_{i,j}^{(K)}(f) = \left[\sum_{l=0}^{L-1} \alpha_{i,j}^{k}(l)\delta(\tau-\tau_l)\right]$ (1)

Where τ_l is the delay of the l^{th} path, and $\alpha_{i,j}^{k}(l)$is the amplitude of the l^{th} path between transmission antenna i and reception antenna j at the k^{th} OFDM block. The $\alpha_{i,j}^{k}(l)$'s are modelled as complex Gaussian random variables with zero mean and variances $E\left|\alpha_{i,j}^{k}(l)\right|^2 = \delta_l^2$ where "E" stands for the expectation. The powers of all the "L" number of paths are normalized in such a way that $\sum_{l=0}^{L-1} \delta_l^2 = 1$.

From (1), the frequency response of the channel is given by

$$H_{i,j}^{(K)}(f) = \left[\sum_{l=0}^{L-1} \alpha_{i,j}^{k}\, e^{-j2\pi f_q T_l}\right] \quad (2)$$

Where $j = \sqrt{-1}$. We assume that the MIMO channel is spatially uncorrelated, that means the channel indices $\alpha_{i,j}^{k}(l)$ are not dependant on the indices (i,j). We consider STF coding among Mt transmit antennas, N OFDM sub-carriers and K OFDM blocks. Each STF codeword can be expressed as a KN *Mt matrix as shown

$$c = [c_1^T \; c_2^T \; c_3^T \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. c_k^T]^T \quad (3)$$

$$C_k = \begin{bmatrix} c_1^k(0) & c_2^k(0) & .. \; .. & c_{M_t}^k(0) \\ c_1^k(1) & c_2^k(1) & .. \; .. & c_{M_t}^k(1) \\ . & . & .. \; .. & \vdots \\ . & . & .. \; .. & . \\ c_1^k(N-1) & c_2^k(N-1) & .. \; .. & c_{M_t}^k(N-1) \end{bmatrix} \quad (4)$$

is the matrix of the channel symbols transmitted in the kth OFDM block and $c_i^k(n)$ is the channel symbol transmitted over the nth sub-carrier by transmission antenna i at the kth OFDM block. The STF code is assumed to satisfy the energy constraints such as $E\,\|C\|_F^2 = KNM_t$. At the kth OFDM block, the OFDM transmitter computes an N-point inverse FFT to each column of the matrix C_k. After adding cyclic prefix, the OFDM symbol corresponding to the ith column of C_k is transmitted by transmit antenna i. At the receiver, after matched filtering, removing the cyclic prefix, and applying FFT, the received signal at the n-th sub-carrier at receive antenna j in the kth OFDM block is given by the equations represented below

$$y_j^k(n) = \sqrt{\frac{\rho}{M_t}} \sum_{i=1}^{M_t} c_i^k(n) H_{i,j}^k(n) + z_j^k(n) \quad (5)$$

$$H_{i,j}^{(K)}(n) = \left[\sum_{l=0}^{L-1} \alpha_{i,j}^k(l)\, e^{-j2\pi n \Delta f T_l}\right] \quad (6)$$

is the channel frequency response at the nth sub-carrier between transmit antenna i and receive antenna j .

V. Weighing Coefficients

One significant issue in the proposed pre-DFT preparing plan for MIMO-OFDM frameworks with space-time-recurrence coding is the computation of the weighting coefficients before the DFT handling. All in all, the weighting coefficients estimation are explicit to the space-time-recurrence coding plan. In this paper, we propose a widespread weighting coefficients estimation calculation that can be applied in most functional space-time-frequency codes, for example, those proposed in prior. This makes the plan of the pre-DFT handling plan free of the streamlining of the space-time-recurrence coding, which is attractive for multiplatform frameworks. All in all, the weighting coefficients before the DFT preparing can be determined accepting that the CSIs are unequivocally accessible. In this paper, we will show that the weighting coefficients can likewise be gotten utilizing the sign space technique without the express information on the CSIs. This assists with lessening the intricacy of channel assessment needed by the space-time-recurrence disentangling since the quantity of identical channel branches needed to be assessed in the proposed plan can be diminished from the quantity of get recieving wires to the quantity of DFT blocks.

$$C^{(t)} = \left[c_{0,1}^{(t)}, .. c_{N-1,1}^{(t)}, \ldots .. \quad c_{0,F}^{(t)} \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. c_{N-1,F}^{(t)}\right]$$
$$t = 0,1,\ldots\ldots\ldots,T-1$$

Where $c_{n,f}^{(t)}$ is the coded information symbol at the nth subcarrier of the tth symbol period of OFDM signal transmitted from the fth transmit antenna, and "T" is the number of OFDM symbols in a STF codeword. When T = 1, the space time-frequency code reduces to a space-frequency code. After the IDFT processing, at the t th OFDM symbol period, the l th sample at the fth transmit antenna is given by

$$S_{t,l}^{(f)} = \frac{1}{N}\left[\sum_{l=0}^{L-1} c_{n,f}^{(t)}\, e^{-j\frac{2\pi l n}{N}}\right] \quad (7)$$
$$-N_q \le l < N, f = 1, \ldots \ldots \ldots \ldots \ldots F, \qquad t = 0, \ldots \ldots \ldots \ldots .. T-1$$

Where Ng is the length of the cyclic prefix, and we assume that (Ng + 1) < N to keep high transmission efficiency.

We will assume that the channel do not vary significantly over the period of one STF codeword. Also, we can assume that the impulse responses of the channel settle to zero during the cyclic extension, or L ≤ (Ng + 1) < N where L is the maximum length of the CIRs. At the m th receive antenna, the l th sample at the t th OFDM symbol period is then given by

$$r_{t,l}^{(m)} = \sum_{f=1}^{F} h_i^{(m,f)} * s_{t,l}^{(f)} + z_{t,l}^{(m)} \quad (8)$$

Where * is the convolution product, and $z_{t,l}^{(m)}$ is the component of the additive white Gaussian noise (AWGN) at the mth receiving antenna. At the receiver section, even before the DFT processing, the data streams received at the reception antennas are weighted and again combined forming the required Q number of branches. After the guard interval deletion, the weighted and combined signals are then applied to the DFT processors. Note that there are Q branches, and hence the number of DFT blocks required at the receiver is also Q. As a result, compared to the general receiver structure, where M DFT blocks are used, the number of DFT blocks used at the receiver can be decreased when pre-DFT processing is used. For the q -th branch, the output of the DFT processor at the t- th OFDM symbol period is given by

$$v_{n,q}^{(t)} = \sum_{f=1}^{F} \sum_{m=1}^{M} w_{m,q} H_n^{(m,f)} c_{n,f}^{(t)} + \sum_{m=1}^{M} w_{m,q} \hat{z}_{t,n}^{(m)} \quad (9)$$

$$H_n^{(m,f)} = \sum_{l=0}^{L-1} H_l^{(m,f)}\, e^{\frac{-j2\pi l n}{N}} \quad (10)$$

$$\hat{z}_{t,n}^{m} = \sum_{l=0}^{N-1} z_{t,l}^{m}\, e^{\frac{-j2\pi l n}{N}} \quad (11)$$

and ωm,q is the weighting coefficient for the m th receive antenna at the qth branch. In order to keep the noise white and its variance at different branch the same, we assume that the weighting coefficients are normalized (i.e., $\boldsymbol{\Omega}^H\boldsymbol{\Omega} = \mathbf{I}Q$, where $\boldsymbol{\Omega}$ is an M × Q matrix with the (m, q) th entry given by $\omega_{m,q}$, and **I**Q is a Q × Q identify matrix).

Prior to applying ensembles to graphs , the upper and lower bound determination is done for the probability of error of codes which are linear in nature .In case of upper boundaries, the focus is mainly on the Gallager bounding techniques. For lower boundaries , we apply de Caen's boundary rules and their improvisation techniques, and sphere-packing bounds with their recent developments which are intended for codes of block length of minimum amount. When the ML decoder is kept to use, the pair-wise error probability (PEP) can be used to denote system performance, which is further determined by the pair-wise codeword distance.

VI. SIMULATION RESULTS

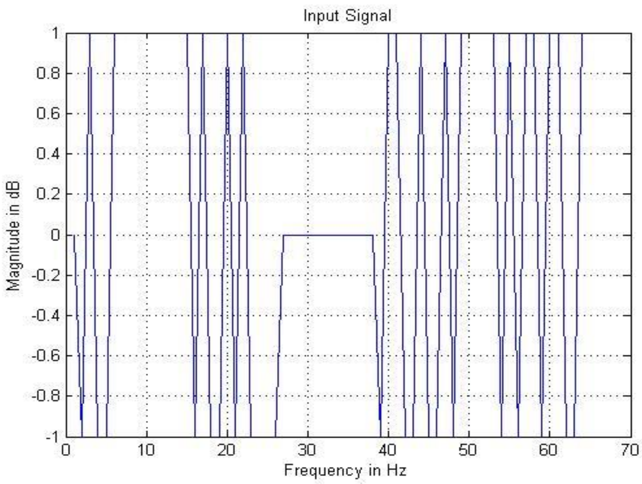

fig. 3 Input Signal to the MIMO-OFDM transmitter

Here, we consider a MIMO-OFDM system with 4 x 4 configuration i.e., 4 transmitters and 4 receivers. Input to the MIMO-OFDM system is generated using the function “rand” in MATLAB software. The same is plotted in the figure 3.

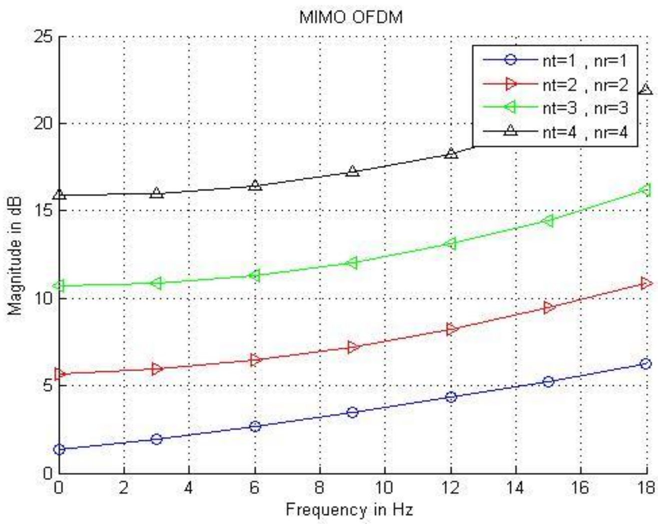

fig. 4 Power vs Frequency plot

The figure 4 corresponds to the plot between magnitude of the power which is directly proportional to the capacity of the channel on the y-axis and the frequency on the x-axis. As we can notice from the graph, more the number of antennas used in the process, more the system capacity increases corresponding to the frequency.

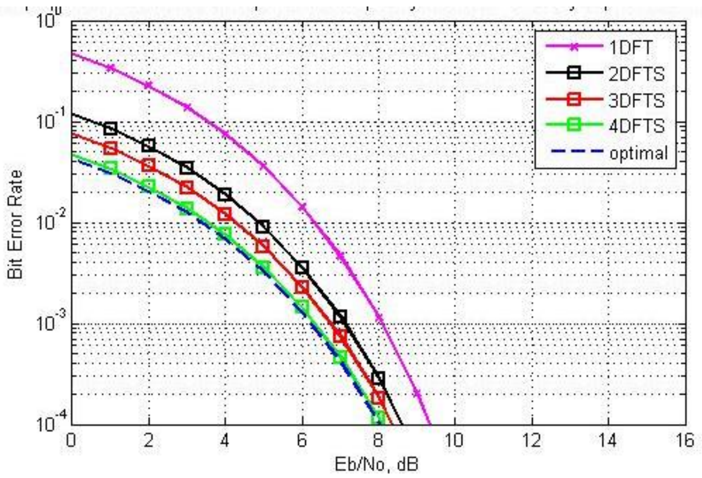

fig. 5 Bit Error Rate performance of the proposed scheme with the space-time-frequency code over a six-ray exponential decay Rayleigh fading channel

As the real time communication channel is a fading channel but not an ideal one, here the system is modelled for the six-ray exponential decay Rayleigh fading channel. This kind of fading channel can be often observed in urban environment where the multiple number of traversal paths are available for the signal being transmitted. The same is depicted in the above graph, in which, with the use of just 4 DFT processing blocks, optimal performance can be attained.

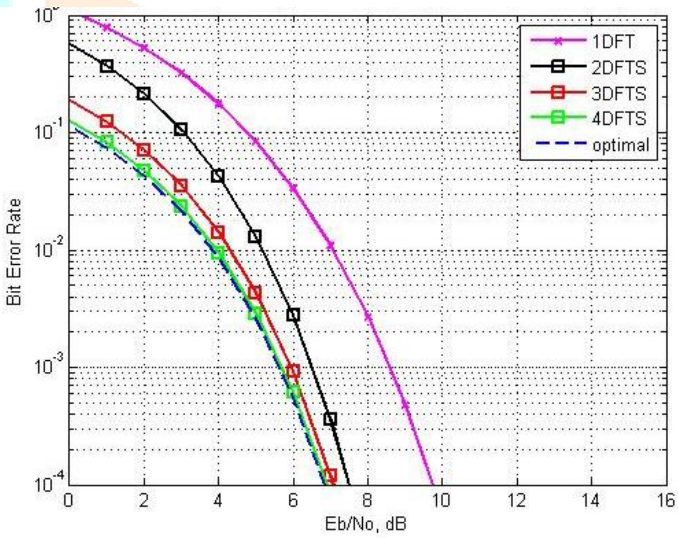

Fig. 6 Bit Error Rate performance of the proposed scheme with the space-time-frequency code over a two-ray equal gain Rayleigh fading channel

Similar to the figure 5, here the system performance is checked over a Rayleigh fading channel with a 2 ray equal gain which can be applicable majorly to less densely constructed areas where the sources of reflection are less and the only 2 paths for a signal are considered. One is the straight ray and another is the reflected ray from the ground. Here also, as the number of DFT blocks keep increasing from 1, the optimal performance can be achieved when only a 4 DFT processing blocks are used. More conclusions follow.

VII. Conclusion

A pre-DFT treatment approach for a MIMO-OFDM framework with Space-time frequency coding was suggested in this paper. By use of MIMO-OFDM in combination helps to meet the demand of users in communication networks. The proposed scheme reduces complexity thus improving the efficiency. It is possible to derive a simple weighting coefficient algorithm. The algorithm can be used with most current functional space-time-frequency codes, according to the theoretical research and simulation results. MIMO OFDM is capable of operating under a wide variety of channel conditions. The number of DFT blocks needed in the proposed framework is decreased to achieve near-optimal system efficiency.

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